



# **VEGA**

## **VULNERABILITY OF ELECTRIC POWER GRIDS ANALYZER**

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*Sponsored by Department of Justice*

**July 2004**



# ***What is VEGA?***

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**VEGA is a tool for analyzing the **vulnerability** and defense of electric power systems under threats posed by terrorist attacks.**

- **VEGA determines the **worst possible** disruption that could be caused by a terrorist attack,**
- **Compares multiple attack plans terrorists might undertake under different **resource-**constrained assumptions,**
- **Assesses **security enhancement** through preemptive measures, and**
- **VEGA is based on powerful **optimization****

# Integrating Three Levels of Optimization



- **Level 1:** Optimal power flow model to **minimize “disruption”**:

(disruption = load shedding + increased costs)

Data: Power grid data

- **Level 2:** Interdiction model to **maximize “Level-1 disruption”**

Data: Power grid data and terrorist resources

- **Level 3:** Protective model to **minimize “Level-2 interdiction”**

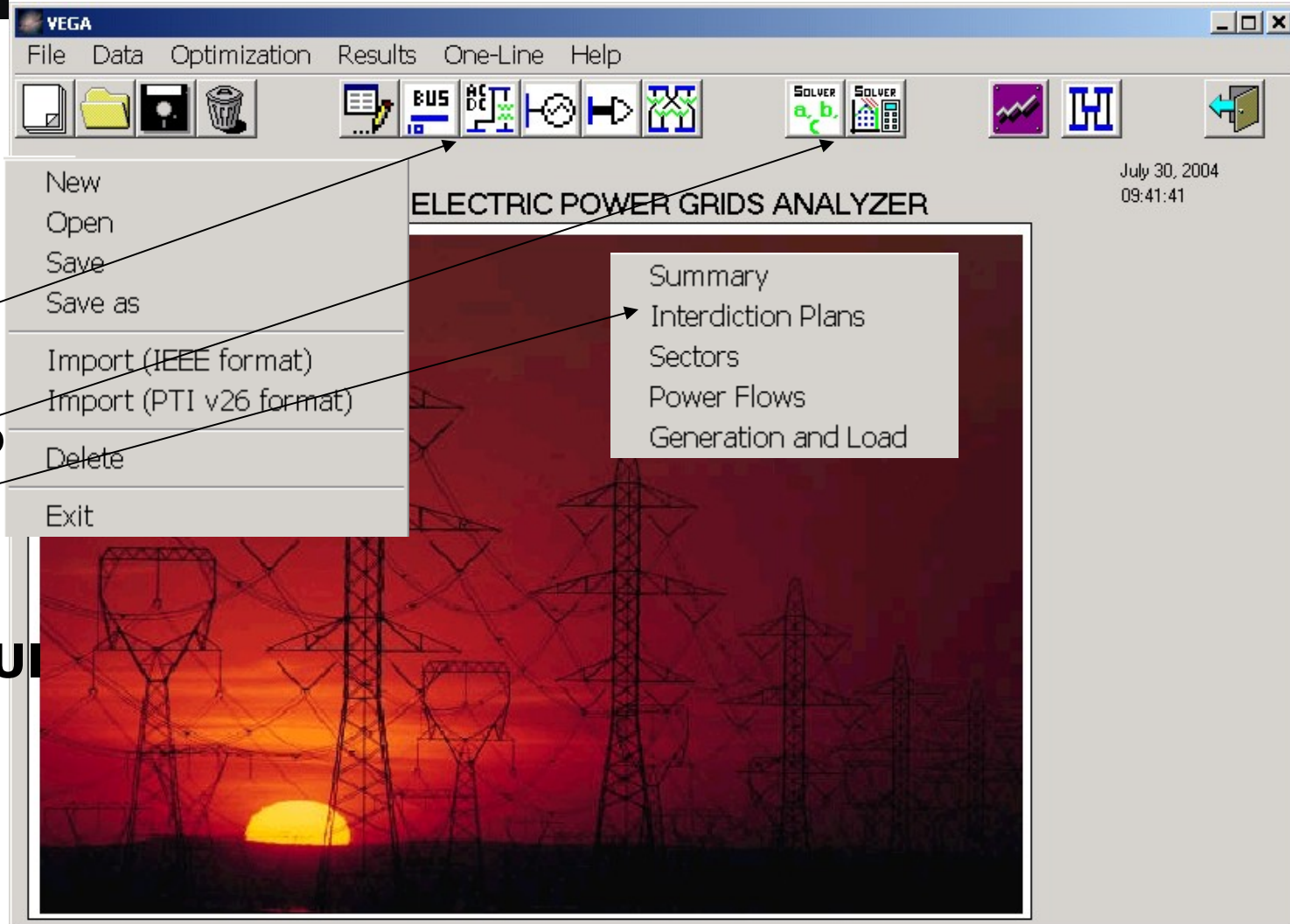
Data: Power grid data, terrorist resource and counter-terrorist resources (budget for expansion, spares, upgrades, hardening)

# VEGA



## Main Menu:

- **File mgmt.**
- **Grid data**
- **Optimization**
- **Results**
- **One-Line GUI**
- **Help**





# Power Grid Data



Line / Transformer Data

Base Load (MW)

LINES ( 69 records)

	Line code	Line Name	From Bus	To Bus	Capacity (MW)	Resistance (p.u.)	Reactance (p.u.)	Interdictable?	Int. Resources
▶	A1	A1	101	102	175.00	0.003	0.014	True	1.00
	A10	A10	106	110	175.00	0.014	0.061	True	1.00
	A11	A11	107	108	175.00	0.016	0.061	True	1.00
	A12-1	A12-1	108	109	175.00	0.043	0.165	True	1.00
	A13-2	A13-2	108	110	175.00	0.043	0.165	True	1.00
	A18	A18	111	113	500.00	0.006	0.048	True	1.00
	A19	A19	111	114	500.00	0.005	0.042	True	1.00
	A2	A2	101	103	175.00	0.055	0.211	True	1.00
	A20	A20	112	113	500.00	0.006	0.048	True	1.00
	A21	A21	112	123	500.00	0.012	0.097	True	1.00
	A22	A22	113	123	500.00	0.011	0.087	True	1.00
	A23	A23	114	116	500.00	0.005	0.059	True	1.00
	A24	A24	115	116	500.00	0.002	0.017	True	1.00

Bus codes (names)

Double click on the bus to select it while the cursor is on the From/To fields of Lines, Transformers or DC Lines Grids

101 (Abel)  
102 (Adams)  
103 (Adler)  
104 (Agricola)  
105 (Aiken)  
106 (Alber)  
107 (Alder)

◀◀ Lines (rec. # 1) ▶▶

Add Line

Delete Line

Lines in parallel

TRANSFORMERS ( 10 records)

	Transf. code	Transf. Name	"From" bus	"To" Bus	At substation	Capacity (MW)	Resistance
▶	A14	A14	109	111	Sub_12	400	
	A15	A15	109	112	Sub_12	400	
	A16	A16	110	111	Sub_12	400	
	A17	A17	110	112	Sub_12	400	
	A7	A7	103	124	Sub_11	400	
	B14	B14	209	211	Sub_22	400	
	B15	B15	209	212	Sub_22	400	
	B16	B16	210	211	Sub_22	400	
	B17	B17	210	212	Sub_22	400	
	B7	B7	203	224	Sub_21	400	

DC LINES ( 0 records)

	DC Line code	DC Line Name	From Bus	To Bus	Capacity
*					

◀◀ Transformers (rec. # 1) ▶▶

Add Transformer

Delete Transformer

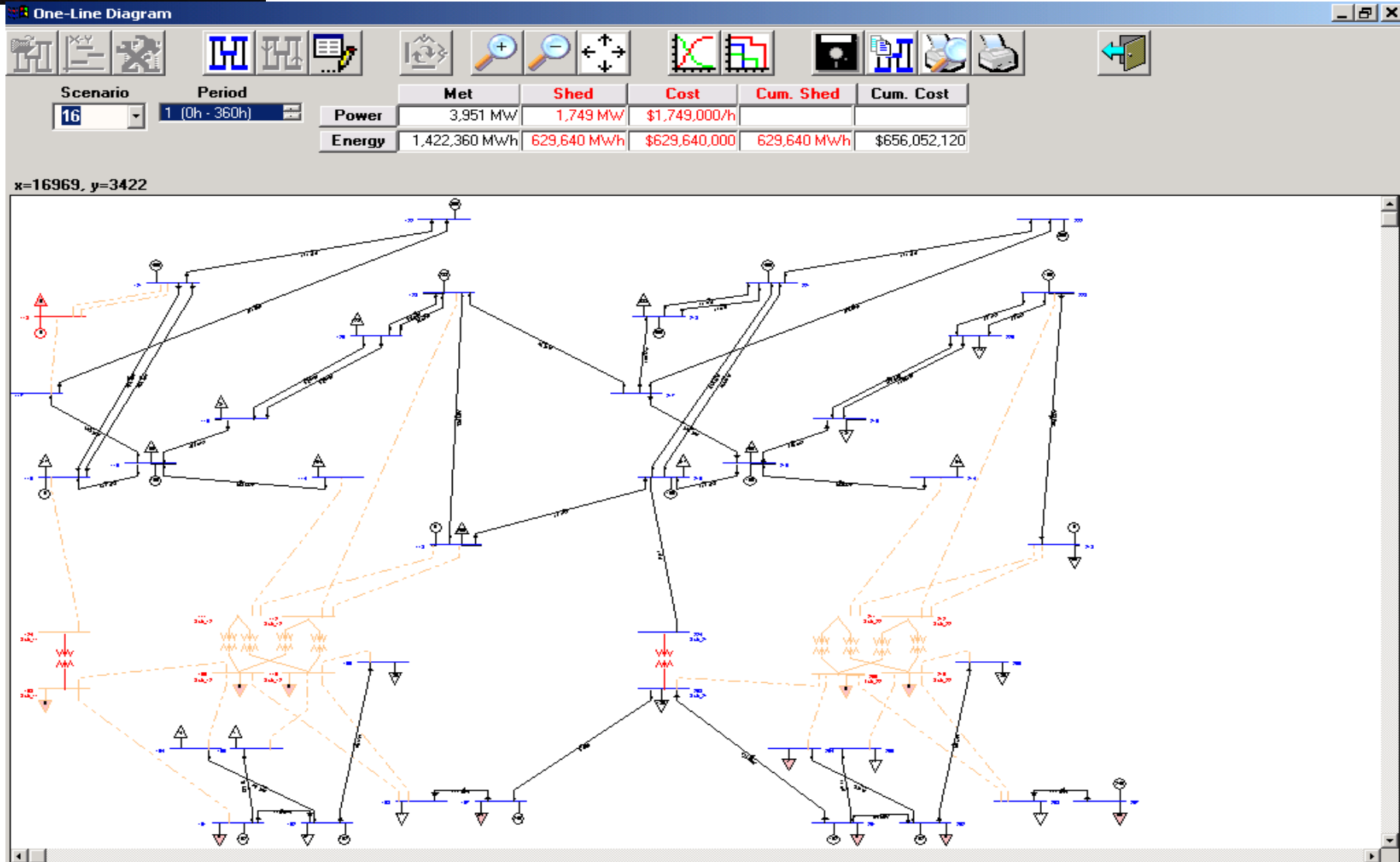
◀◀ DC Lines ▶▶

Add DC Line

Delete DC Line

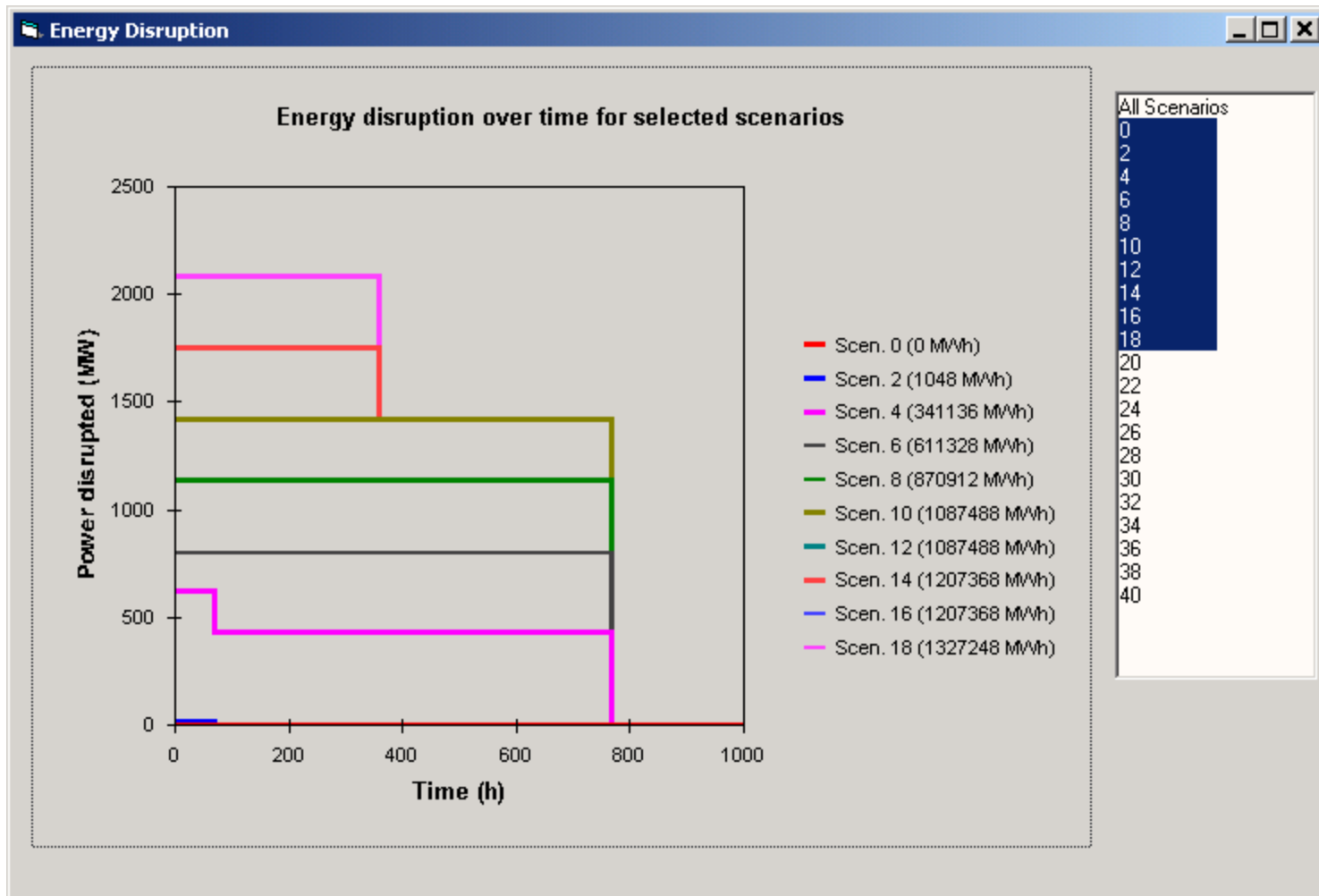


# One-Line GUI: Power Flow After Optimal Interdiction





# Energy Disruption over Time



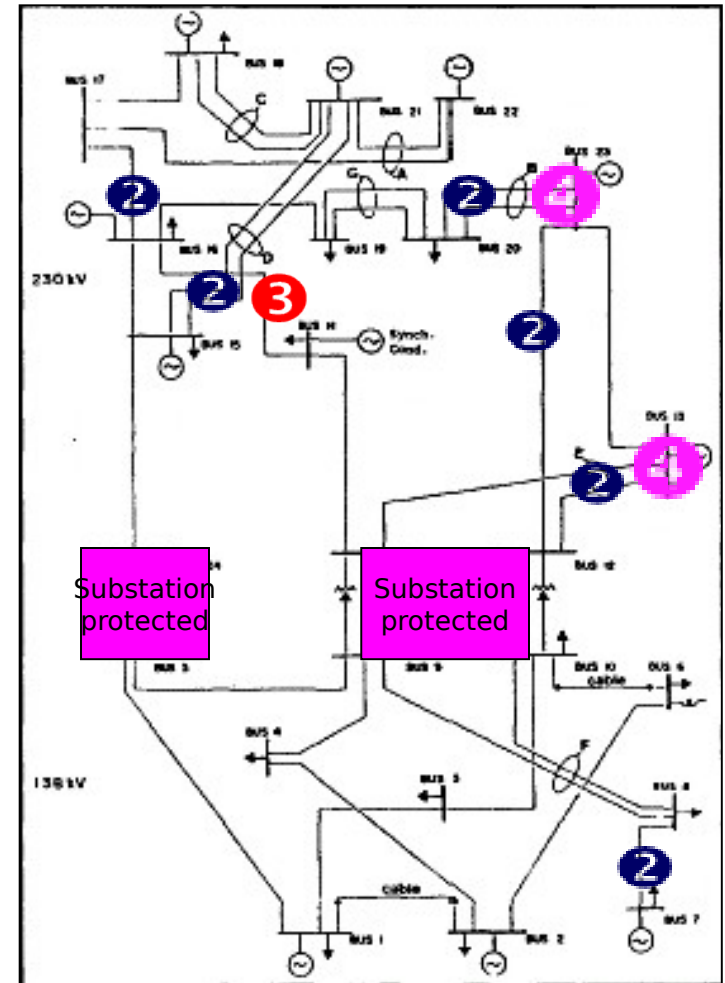
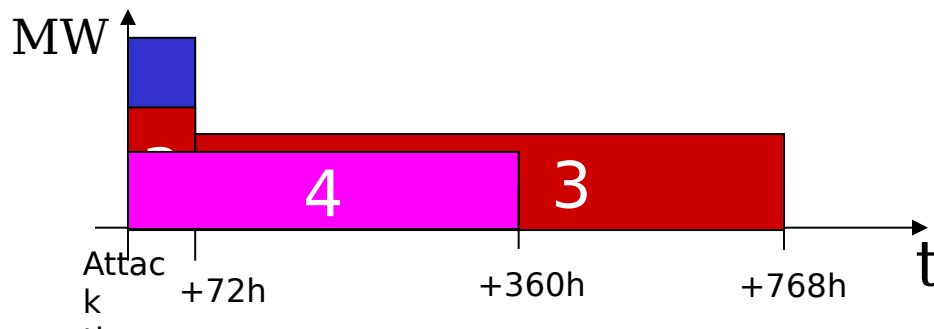


# Optimizing Disruption over Time with System Restoration



Total Load: 2,850 MW

Attack Plan	Time Period	Power Shed (MW)	Energy Shed (MWh)
2	0-72 h	1,373	98,856
	Total: 98,856 MWh		
3	0-72 h	902	64,944
	72-768 h	708	492,768
	Total: 557,712 MWh		
4	0-360 h	756	272,160
	Total: 272,160 MWh		



Salmeron, Wood and Baldick, *IEEE Trans. on Power Systems*, May 2004





# ***Technical Features***

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- **Hardware**

- 500 MHz processor

- 1Gb RAM

- **Operating system**

- Windows 98, 2000, XP or above



# Prototype Features

	VEGA 1.0	VEGA 2.0	VEGA 3.0
<b>Expected date</b>	J un-03	J un-04	J un-05
<b>Database interface</b>	X	X	X
<b>Network interface</b>	X	X	X
<b>Grid size limit</b>	100 buses	1000 buses	1000+ buses
<b>Disruption analysis</b>	Pseudo-optimal	Optimal	Optimal
<b>Disruption period</b>	Short-term	Short- and Long- term	Short- and Long- term
<b>Analysis of protective measures</b>	Manual	Manual	Optimized automatically